BEYOND EINSTEIN: From the Big Bang to Black Holes

Constellation X

The Constellation X-Ray Mission

Atlas –V Single Launch Configuration: Mirror Design

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Agenda

- Design "Rules"
- Spacecraft concepts
- Mirror Designs

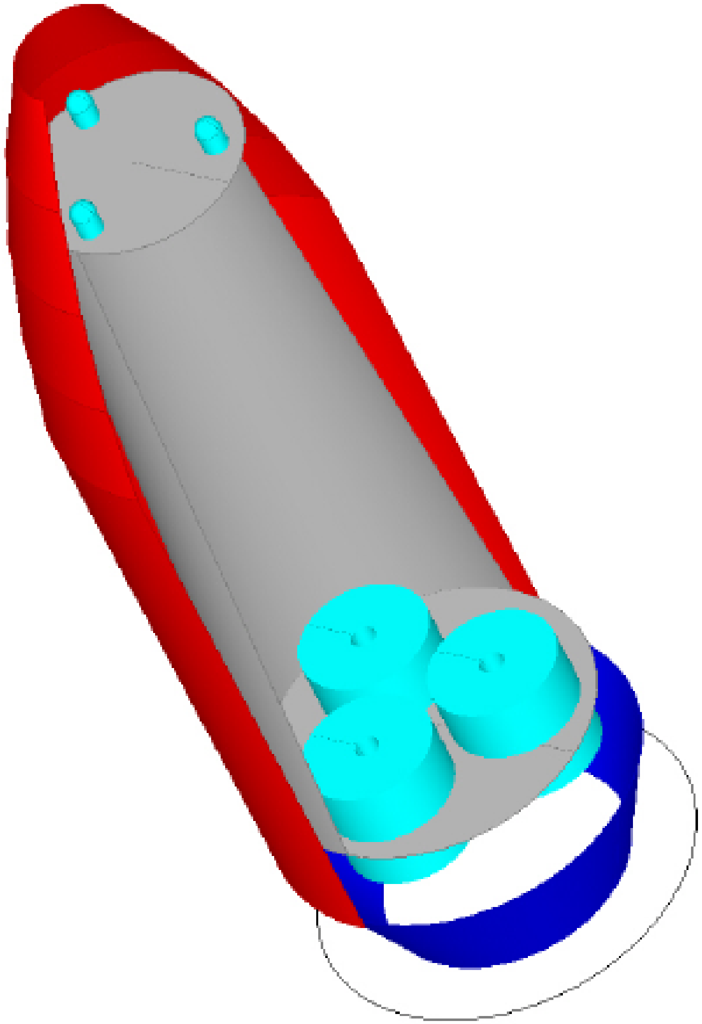
Design Rules

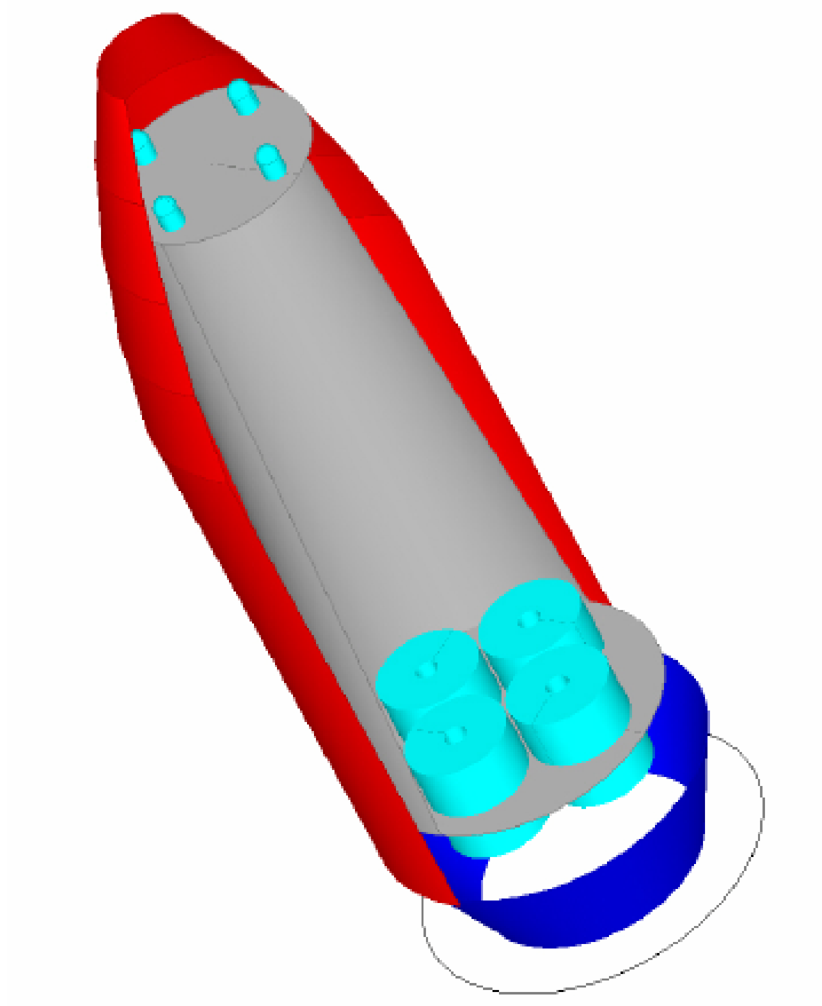
- **Single launch, single spacecraft**
  - significant cost savings
  - possibility of launching sooner
- **Remove 12 HXTs, 4 RGSs, but will be able to include 1 or 2 SEPs**
- **Maintain as much effective area and margin as possible, while also tracking closely SXT EA for E > 10 keV**
- **Simplicity, low cost**
  - keep focal length at 10 m (no extendible optical bench)

Spacecraft Concepts

- Quickly settle upon 3 and 4 SXT designs
- Mass is tightest constraint
  - attempt to maintain 30 per cent mass margin
    - P/L mass limit for L2 ~ 6500 kg
  - used component masses for Delta IVH single launch configuration
    - 4 1.6 m OD SXTs, 4RGSs, 12HXTs, 10 m FL, 1 s/c
  - eliminate/scale component mass as appropriate
  - flight mirror assembly mass (structure+glass) is a significant mass driver (~ 45 per cent of P/L, including propellant)
    - assume structure mass scales with glass mass
- Mass constraint drives mirror design
  - glass mass
  - number of "shells"
  - diameter of shells
- P/L fairing dynamic envelope determines maximum OD of SXTs

Spacecraft Concepts





Reference Point

- Baseline Design
  - 1.6 m outer diameter
  - 0.3 m inner diameter
  - shell to shell spacing consistent with mirror length (200 mm) and 1.25 arc-min (rad.) unvignetted FOV
  - 230 shells, divided into a set of 12 outer and 6 inner modules
    - 30 and 60 deg span, respectively
    - angular span of modules determined by maximum available size of glass substrates
  - 460 mandrels (2/shell – 1 @ for P and H)
  - 3660 mirrors/SXT, 14640 mirrors total, excluding spares

Mirror designs

- Use maximum outer diameter consistent with fitting within payload fairing dynamic envelope
- 3 SXT design: 1.5 m OD (previously was 1.6 m)
  - same mirror design as baseline design and still meets mass constraint
  - inner diameter = 0.3 m
  - shell to shell spacing designed for 1.25 arc-min (rad) unvignetted FOV
- 4 SXT designs:
  - max allowable OD 1.3 m
  - tried designs with 1.2 and 1.3 m OD
  - if maintain same shell to shell spacing as baseline, mass constraints limit the inner diameter to ~ 0.5 m
    - reduces high E effective area
  - so, increase shell to shell spacing to cover the full range of graze angles to the 0.3 m minimum ID to improve high E response

Mirror designs – II

- 4 SXT designs (cont'd)
  - tried a variety of designs using design FOV to adjust shell to shell spacing to meet mass constraint and occupy full range of diameters:
    - 1.2 m OD 0.43 m ID "1.25 arc-min" unvignetted FOV
    - 1.3 m OD 0.5 m ID 1.25 arc-min FOV
    - 1.3 m OD 0.3 m ID 10 arc-min FOV
      - » single module design
      - » 36 deg wide module
    - 1.3 m OD 0.3 m ID 6 arc-min FOV
      - » inner+outer module design
      - » 36 deg and 72 deg wide modules

Comparison of 4 SXT Designs

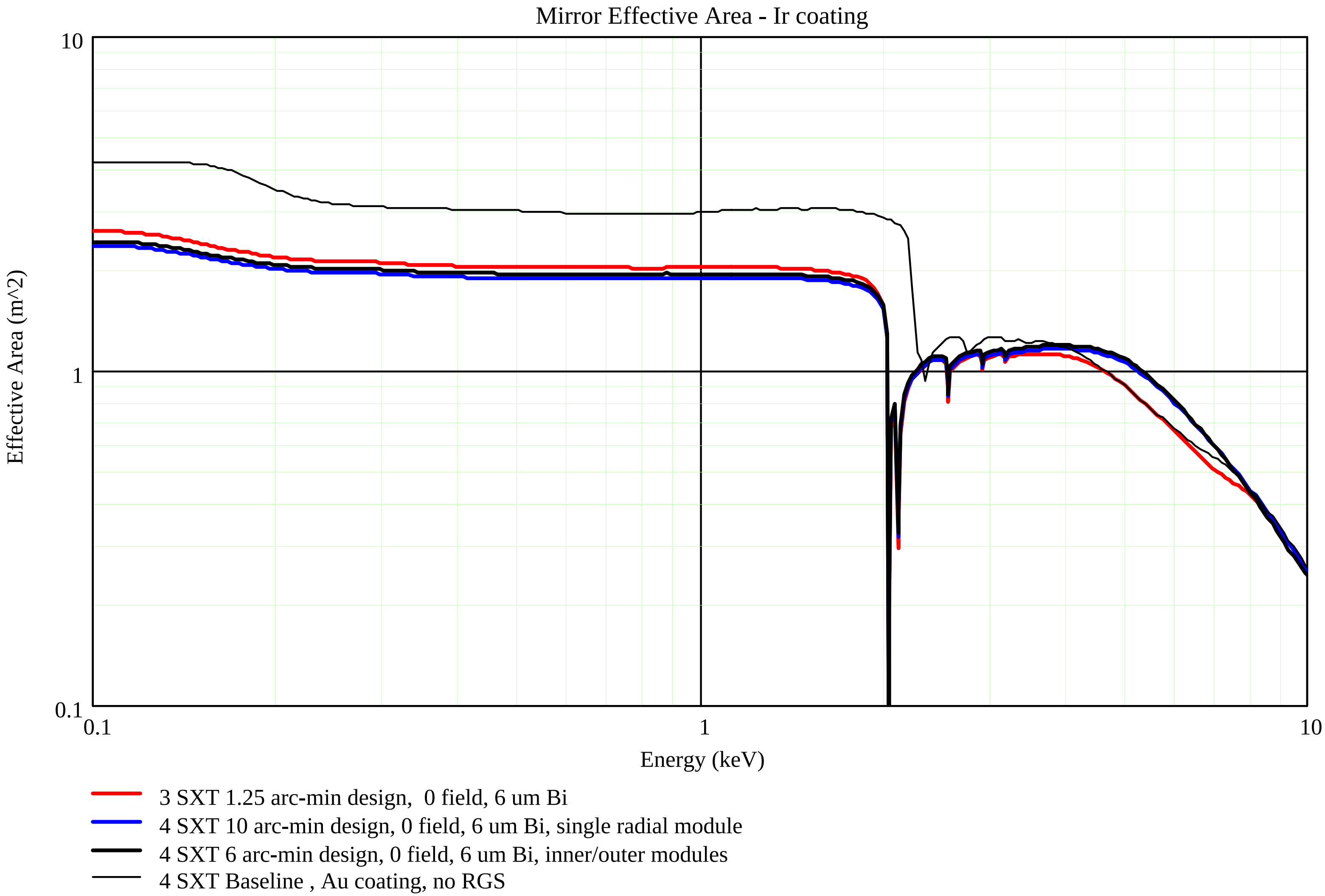
- Single Radial Module
  - 163 shells
    - •163 mandrel pairs
  - 10 modules/SXT
    - •163 shells/module
    - •Rmax/Rmin = 0.65m/0.15m
  - 13040 mirrors/4 SXTs

- Advantages (excluding performance)
  - simpler FMA design
  - less module/module alignment
  - all modules identical
  - easier to test diametrically opposed modules full ap in x-ray
  - more space between shells

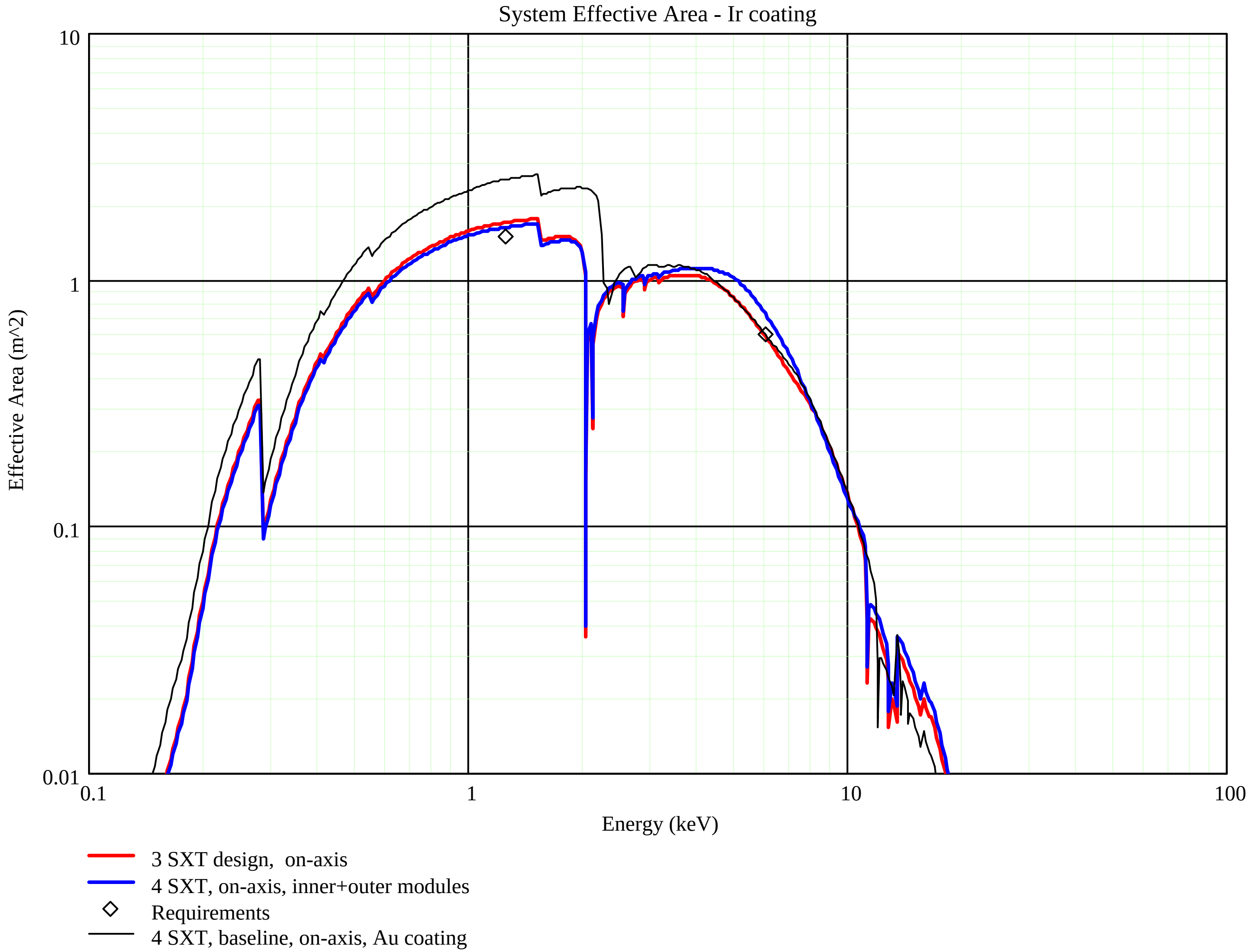
- Inner/Outer Module
  - 163 shells
    - •163 mandrel pairs
  - 15 modules/SXT
    - •97 shells/outer module
      - » Rmax/Rmin = 0.65m/0.325m
    - •66 shells/inner module
      - » Rmax/Rmin = 0.289m/0.15m
  - 10320 mirrors/4 SXTs

- Advantages (excluding performance)
  - fewer mirrors to make/align
  - less time to assemble/module
    - •more modularity
  - larger inner-most mirrors

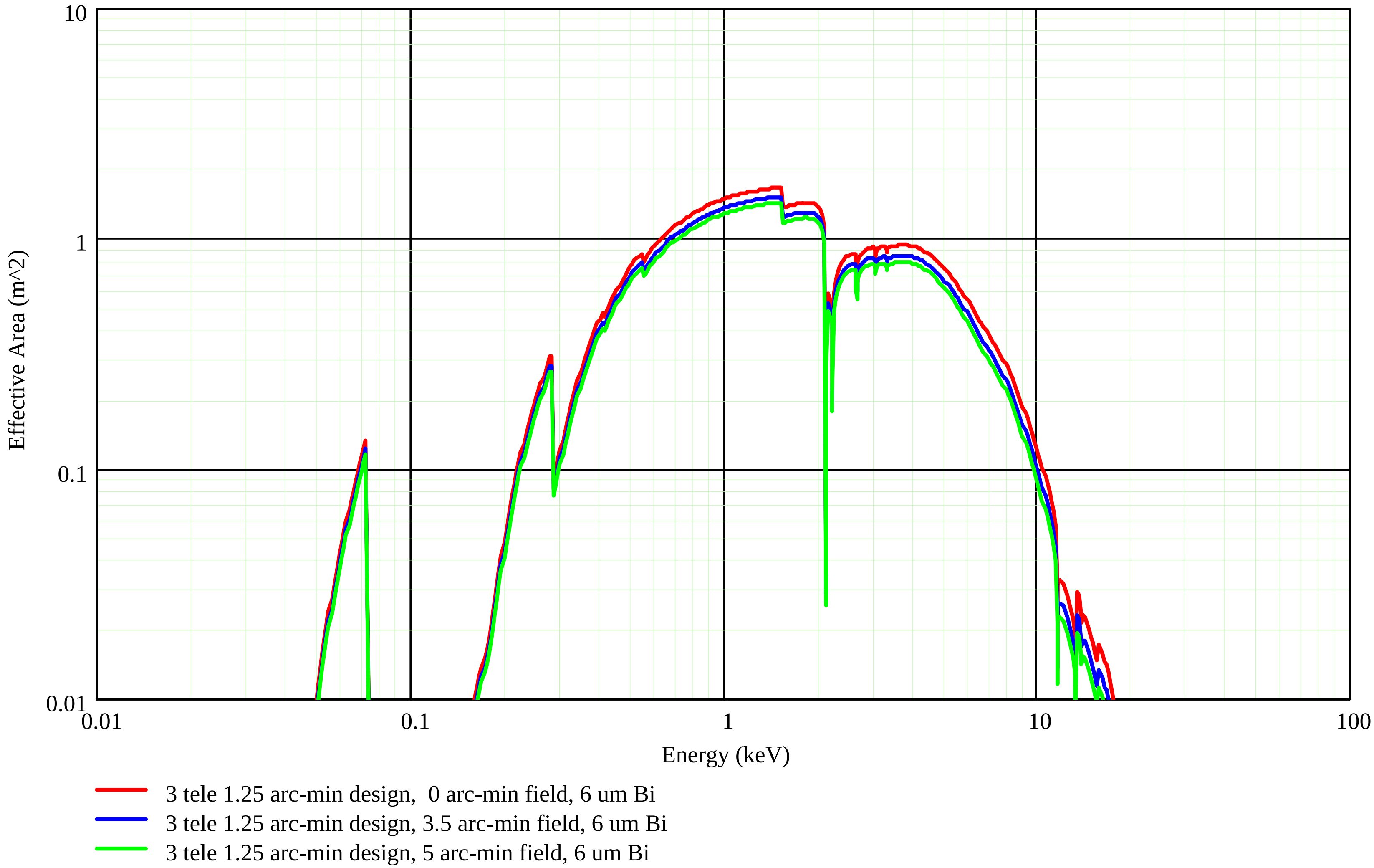
Mirror-only EA: Comparison of 3 and 4 SXT designs



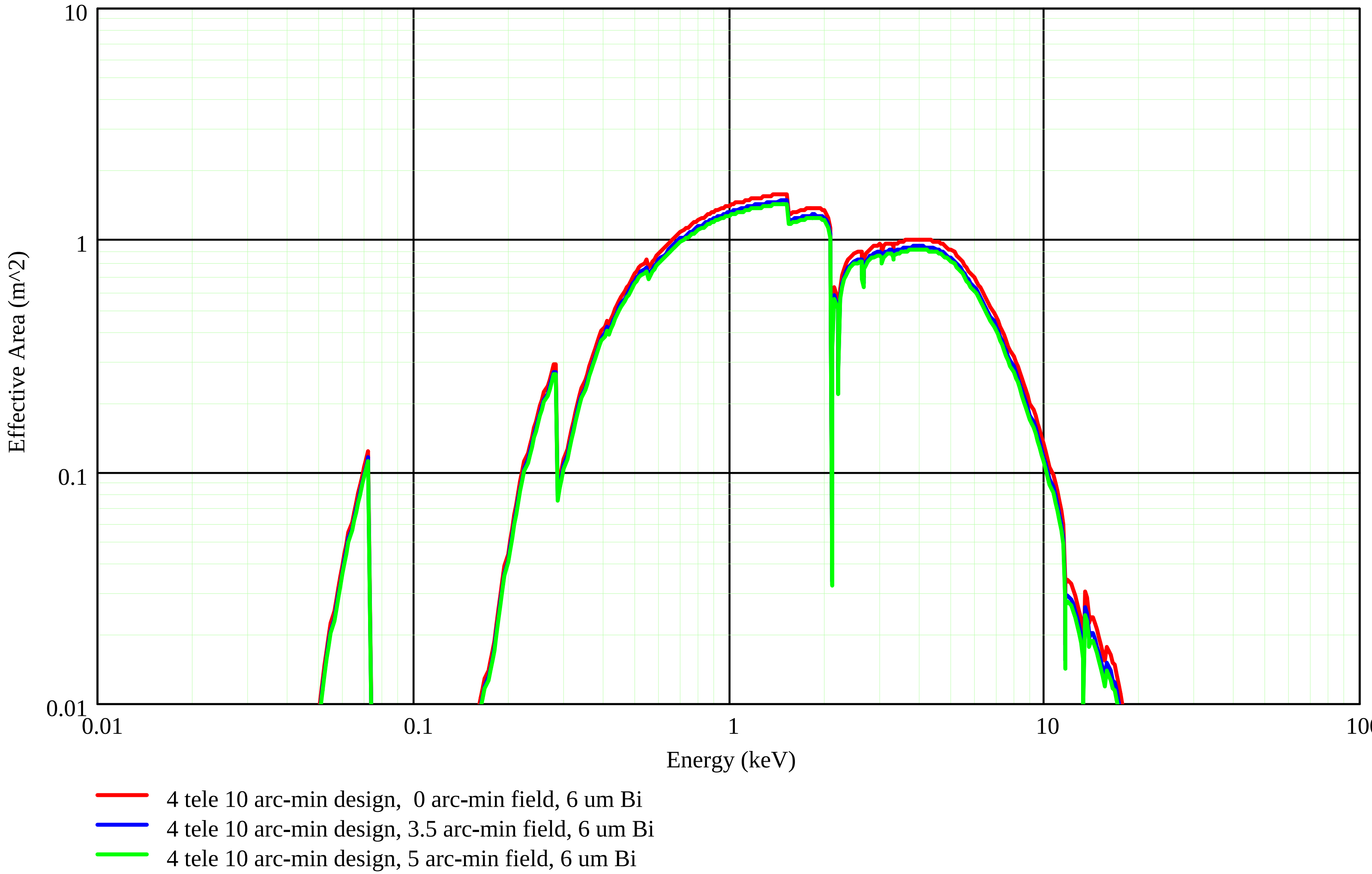
System EA: Comparison of 3 and 4 SXT designs



Vignetting off-axis: 1.25 arc-min design



Vignetting off-axis: 10 arc-min design



Summary

- 4 x 1.3 m OD, 6 arc-min unvignetted design with inner and outer modules offers good balance of performance relative to requirements and baseline performance.
  - loss of EA at low energies, but performance consistent with requirements
  - use of Ir compensates for fewer shells than baseline, giving improved performance at E > 3 keV
- Larger shell to shell spacing provides secondary benefit, as yet un/under-utilized, of less off-axis vignetting
  - stray light issues of larger shell to shell spacing need to be examined
    - may enable use of aperture plates
    - may allow larger “single-bounce” flux w/o aperture plates
- Fewer mandrels and mirror segments support reducing program cost and schedule